

## **701 PILING**

### **701.01 DESCRIPTION**

Piles shall be of timber, precast reinforced concrete, precast prestressed concrete, cast-in-place concrete with steel casing or steel H-beam, as specified, constructed and driven in accordance with these specifications, and as indicated on the drawings or as directed.

### **701.02 MATERIALS**

The materials for piles and splices shall be as indicated on the plans and Special Provisions and shall conform to 816.

Concrete shall conform to 817.

Reinforcement shall conform to 812.02.

Prior to driving any pile, the Contractor shall submit written certification from the manufacturer that the materials meet the requirements of the specifications. Certified mill test reports shall be submitted for steel piles.

### **701.03 PREPARATION FOR DRIVING**

Piles shall not be driven until after the excavation is completed.

When piles are located in embankment fill 5.0 feet or greater in depth, an augured hole through the embankment will be required for each pile location. The augured hole shall not be carried into the original material beneath the embankment construction. Holes shall be drilled with a power auger. They shall be clean and equal to or slightly larger than the maximum cross-section of the pile. If holes are left overnight, they must be protected or be re-augured the following day. Augured holes shall be filled with sand or other suitable material after driving piles.

### **701.04 DRIVING**

**(A) GENERAL.** Piles, including Length Test Piles and Load Test Piles if required, shall be driven only in the presence of the Engineer.

Permanent piles shall not be driven until test piles for the particular section have been driven, tested and approved by the Engineer. No pile shall be driven within 20 feet of new PCC foundations which have cured for less than 14 days.

If a load test is required, permanent piles shall not be driven until the load test data have been analyzed and permission is obtained from the Engineer. No pile driving is permitted within a radius of 100 feet of any pile load test during load testing operations.

The hammer used to drive permanent piles shall be of the same size, type and manufacture as the hammer used to drive length test piles.

Each pile shall be driven continuously from the start of driving until the bearing capacity is secured. Unless specifically authorized by the Engineer, intermittent driving to secure increased bearing values will not

be permitted.

Piles shall be driven at least to minimum pile tip elevations and pile design loads indicated in the contract documents. If the indicated pile design load is not attained when the minimum pile tip elevation is reached, driving shall continue until the Engineer is satisfied that the pile design load is attained.

If extremely hard pile driving conditions exist and/or "practical refusal" is reached at a elevation higher than the specified minimum pile tip elevation, the pile tip elevation may be modified, but only with prior approval of the Engineer.

Unless otherwise determined by the Engineer, "practical refusal" shall be defined as the conditions reached when the actual driving bearing capacity of piles is as follows:

1. 3.0 times pile design load for design loads of 40 tons or less per pile.
2. 2.5 times pile design load for design loads greater than 40 tons per pile.

Piles shall be stored and handled so as to avoid injury and shall be picked up in a manner that will avoid bending, distortion, or twists.

**(B) HAMMERS.** Piles may be driven with approved diesel hammers, gravity hammers, air hammers or with single or double-acting steam hammers of such capacity and in such manner that the piles will be driven to the depths and load capacities required without injury or damage to the piles. The use of gravity hammers on concrete piles will not be allowed. Unless specifically outlined on the plans, the following minimum requirements will apply: Gravity hammers shall weigh not less than 3,000 pounds. The fall shall be regulated so as to avoid injury to the piles and shall in no case exceed 15 feet. When diesel, air or steam hammers are used, manufacturer's rated hammer energy shall be not less than 15,000 foot pounds per blow for pile design loads of less than 40 tons per pile, and not less than 18,000 foot pounds per blow for pile design loads of 40 tons per pile or greater. If required pile penetration is not obtained with hammers meeting above requirements, hammers shall be provided which give the greater output needed. Sonic or other type hammers may be used only with prior written approval.

**(C) LEADS.** Piles shall be held in fixed leads during driving. In lieu of fixed leads the Contractor may use, with the prior approval of the Engineer, any method in which the pile is properly guided and supported and the hammer guided and rigidly supported independently of the pile. Leads shall be adjustable as to batter and shall either be telescopic or of such length as to extend from the highest point to the lowest point which the hammer must travel.

If swing leads are used, all piles shall be driven with templates of type, size and in locations approved by the Engineer.

**(D) FOLLOWERS.** Followers meeting the approval of the Engineer may be used if necessary in driving of piles, but shall be operated in conjunction with the telescopic or extension leads. When a follower is used, one pile in any group of ten shall be a long pile driven without a follower, and shall be used as a test pile to determine the average bearing power of the group. The intent of this specification is that the leads and hammer, or the leads and a suitably braced follower, follow the pile head and support it throughout the entire driving period.

**(E) ACCURACY OF DRIVING.** All piles shall be located accurately as to position and batter; and any

pile driven out of place or injured in driving shall be pulled and redriven or replaced as may be directed by the Engineer, at the sole expense of the Contractor. No variation greater than 1/4 inch per foot from the vertical or specified batter will be acceptable, and the top of each driven pile shall not be out of position by more than 6 inches.

**(F) BEARING CAPACITY OF PILES.** All piles shall be driven to the minimum bearing capacity specified on the plans or in the Special Provisions. Determination of pile capacity, except for the load tested pile, will be based on the following formulae:

$$P = \frac{2WH}{S + 1.0} \quad \text{for gravity hammers}$$

$$P = \frac{2WH}{S + 0.1} \quad \text{for single-acting power hammers}$$

$$P = \frac{2(E)}{S + 0.1} \quad \text{for double-acting power hammers}$$

W = Weight, in pounds, of striking parts of hammer

P = Safe bearing capacity in pounds

H = Height of fall in feet

E = Energy per blow, actual foot pounds

S = Average penetration in inches per blow for the last 5 to 10 blows for gravity hammers, and for the last 10 to 20 blows for power hammers.

The above formulae are applicable only when:

1. The hammer has a free fall.
2. The head of the pile is not broomed or crushed.
3. The penetration is reasonably quick and uniform.
4. There is no appreciable bounce of the hammer after the blow.
5. A follower is not used.

In the event of hammer bounce, twice the height of the bounce shall be deducted from H to determine its value in the formulae.

The manufacturer's rated energy per blow will not be used in bearing capacity formulas; this energy will be determined by the Engineer. No allowance will be made for hammer bounce or spring action in computation of energy per blow. For diesel hammers, the energy rating to be used in bearing capacity formulae shall be as follows:

1. 85 percent of the manufacturer's rated energy per blow for a double acting (enclosed ram) hammer.
2. 75 percent of the manufacturer's rated energy per blow for a single-acting hammer.

The foregoing formulae shall be used as guides only. In all cases the Engineer will be the sole judge as to the final tip elevation of all piles.

**(G) CUTOFFS AND CLEANUP.** Cutoffs shall be made in one plane at the correct elevation or

elevations shown on the plans. In general, the length of pile shall be sufficient to permit the complete removal of all material injured by driving. All cutoffs shall become the property of the Contractor and shall be removed from the site. Any material forced up between the piles and all loose and displaced material around the piles shall be removed to the correct elevations, leaving clean solid surfaces to receive the concrete. Such material is to be removed at the Contractor's expense.

**(H) LENGTH OF PILES.** Unless otherwise outlined on the plans, piles shall be driven to a minimum depth of penetration of 10 feet, measured from the cutoff elevation to the tip of the pile, except that when driven in fill areas, the minimum depth of penetration shall be 10 feet below undisturbed ground.

## **701.05 LENGTH TEST PILES AND LOAD TESTS**

**(A) GENERAL.** When required, the Contractor shall test piles at the locations shown on the plans or designated by the Engineer. These piles shall be of sufficient length to provide for any variation in soil conditions. They shall be driven to the requirements as specified herein. Piles thus driven, if in a planned pile location and if a satisfactory bearing is obtained, shall become permanent structure piles.

No load test piles shall be driven until length test piles are driven to practical refusal and evaluated by the Engineer. Load tests shall be performed at locations and upon piles shown on the plans or as designated by the Engineer. The number of pile load tests may be increased or decreased by the Engineer. Piles selected for load testing shall be tested as individual vertical foundation piles driven to the minimum bearing capacity called for in the contract documents, to determine the relationship between load applied and pile reaction.

The hammer used for Length Test Piles and Load Tests shall be of the same type and manufacture that the Contractor proposes to use for all pile driving under this contract.

The method of loading, bracing, etc., and the facilities for observing the load test and measuring settlements will be at the option of the Contractor; however, prior to testing, the Contractor shall submit plans for approval showing in sufficient detail the methods and equipment he proposes to use. The bracing for the pile shall be completely in place before any test load is applied and shall remain in place until after the completion of the load test. Loading shall not be started until 48 hours after completion of driving, and is subject to the Engineer's approval.

Prior to any loading application, the Contractor shall submit the Engineer certification from an acceptable testing laboratory that all appropriate equipment (i.e. jacks, pressure gauges, etc.) have recently been properly calibrated.

The Contractor shall furnish the Engineer with adequate facilities for making settlement readings 24 hours per day, including lighting and shelter from rain, wind and direct sunlight in the instrumented area. The Contractor shall assign an employee, who fully understands loading and test equipment procedures, to be present during each entire load test.

The Contractor shall be responsible for each load test, and any pile failing to meet the Engineer's approval, whether because of damage while driving or any other reason, shall be withdrawn, and a new pile driven at the Contractor's expense. All movement readings will be recorded by the Engineer and the Contractor shall neither add nor remove loading increments until permitted by the Engineer.

If a hydraulic jack is used, its capacity shall be not less than 225 percent of the pile design load indicated on the plans.

The detailed method of applying, measuring and recording load tests shall be submitted in writing to the Engineer for approval prior to pile testing and shall include sufficient sketches to fully illustrate proposed method. Any loading platform used shall have a safe capacity of 4 times the pile design load indicated on the plans.

If steel H piles are used for reaction or anchor piles, the jacking or reaction beam shall be held down by positive rigid connections to steel H sections. Cable tie-downs will not be permitted. The distance from the test pile to any reaction pile shall be not less than 5 feet measured from center to center.

If reaction or anchor piles are driven at permanent pile locations and meet all specification requirements, payment for such piles will be made at the contract price for Piles. Reaction or anchor piles which are not permanent piles as determined by the Engineer shall, at the direction of the Engineer, be left in place or be pulled out and the hole backfilled with sand.

The test load shall be concentrically applied as near the ground surface as practicable and by such method that the test load acting on the pile at any time may be definitely determined and controlled.

If in the opinion of the Engineer the test pile is found to be in satisfactory condition at the conclusion of the load test, it shall be completed and incorporated into the structure as a permanent pile.

If the Engineer determines the test pile has not met requirements, the pile shall be withdrawn and a new one driven or spliced as needed and driven to required depth after pile tip elevations are determined from new test piles.

Upon completion of the test, all temporary work in connection therewith shall be removed.

The heads of the piles tested shall be cut to the proper elevations required to conform to plans and the resulting cutoffs shall become the property of the Contractor and be removed from the site.

**(B) STANDARD LOAD TEST.** The load shall be applied in sequential increments of 25, 50, 75, 100, 125, 150, 175 and 200 percent of the pile design load indicated on the plans.

Methods satisfactory to the Engineer for obtaining measurements of vertical movements shall be furnished. Readings of these vertical movements made to an accuracy of 0.001 inch shall be taken before and after the application of each new load increments and 2, 4, 8, 15, 30, 60 minutes, and every 2 hours until application of the next load increment.

Additional load increments shall not be applied until rate of settlement caused by previous load increments less than 0.01 inch in one hour, or until at least 2 hours have elapsed, whichever occurs first.

Full test load of 200 percent of the pile design load indicated on the plans shall be maintained on the pile for a minimum period of 48 hours, or such additional time as stipulated by the Engineer. Settlement readings will be taken at the beginning and at the end of the period, and at 4 hour intervals during the period.

If all settlement has ceased or if no progressive settlement occurs during the last 4 hours of the 48 hour test, the unloading of the pile may begin. However, if any progressive settlement is observed during the last 4 hours of the 48 hour test, the full load test shall be maintained on the pile for an additional 12 hours; during the last 4 hours of this additional period the pile shall not show continued settlement.

During the unloading of the pile, the rebound shall be measured when the load remaining on the pile amounts to 75, 50, 25, 10, and 0 percent of the full test load, which decrements of load released at no less than one hour intervals. Rebound readings shall be taken immediately before and after removal of each decrement. Final rebound readings shall be taken 24 hours after the entire test load has been removed; or at more than 24 hours if the Engineer determines that the pile continues to rebound slowly.

Unless otherwise evaluated by the Engineer, the safe allowable load will be considered as 50 percent of the load which, after a continuous application, for a minimum period of 48 hours and for extended periods if required by the Engineer, produces a net permanent settlement not greater than 0.25 inch measured at the top of the pile.

**(C) QUICK LOAD TEST.** Quick Load test shall be in accordance with ASTM D-1143.81. The load shall be applied in increments of 10 to 15 percent of the proposed design load with a constant time interval between increments of 2-1/2 minutes. Load increments shall be added until continuous jacking is required to maintain the test load or until 200 percent of the pile design load is reached, whichever occurs first, at which time the jacking shall be stopped. After a 5 minute interval, the full load shall be removed from the pile in four approximately equal decrements with 5 minutes between decrements.

Readings of time, load and settlement shall be taken and recorded immediately before and after the application of each load increment and at intermediate time intervals as directed. After the maximum load has been applied, readings shall be taken and recorded when the jacking is stopped, after 2-1/2 minutes, and again at 5 minutes thereafter. Readings of time and rebound shall be taken and recorded after all load has been removed, after 2-1/2 minutes, and again at 5 minutes thereafter.

## **701.06 STEEL H PILES**

The Contractor may, at his option, splice pieces of steel H- piles to secure the lengths required; however, only one splice per pile will be permitted. Splices shall be shown on the plans or as approved by the Engineer. Pile lengths shorter than 5 feet will not be permitted. Insofar as practicable, the splice will be located so that its final position will be in firm material underlying the foundation. All splice material shall conform to 815.01(A) or (B). Splicing in the leads will not be permitted unless approved by the Engineer. All welding shall be done by the electric-arc process and shall conform to the specifications of AASHTO/AWS D1.5 as modified by AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges.

All temporary and permanent pile splice welds shall be made only by welders qualified in accordance with 706.18(C). No jet welding will be permitted without prior written approval from the Engineer.

## **701.07 CAST-IN-PLACE CONCRETE PILES (STEEL CASING)**

**(A) INSPECTION OF METAL SHELLS.** At all times prior to the placing of concrete in the driven shells, the Contractor shall have available a suitable light for the inspection of each shell throughout its entire length. Any improperly driven, broken or otherwise defective shell shall be corrected to the satisfaction of the Engineer, by removal and replacement, or the driving of an additional pile, at the sole expense of the Contractor.

**(B) SPLICING.** Splicing of steel shells shall be in accordance with the manufacturer's recommendations.

**(C) REINFORCEMENT.** Unless otherwise shown on the plans, Cast-In-Place Piles shall have reinforcement extending 20 feet into the pile measured from the cutoff elevation.

**(D) DRIVING.** For special types of piling, pile-driving heads or caps, mandrels, or other device, in accordance with the manufacturer's recommendation for the particular type of pile specified, shall be provided to protect the pile head against damage during pile driving and hold the axis of the pile in line with the axis of the hammer.

**(E) PLACING CONCRETE.** All pile shells in a footing shall preferably be fully driven before any are filled with concrete, but in no event shall concrete be placed in a shell, until all driving within a radius of 15 feet has been completed. Shells shall be cut off at the required elevation and shall be free of water when concrete is placed.

## **701.08 PRECAST REINFORCED CONCRETE PILES**

**(A) FORM WORK.** Forms for precast concrete piles shall conform to the general requirements for concrete formwork as specified under 703.

**(B) REINFORCEMENT.** Reinforcement shall be placed in accordance with details shown on the plans, and as outlined in 704.

**(C) CASTINGS.** The piles shall be cast in a horizontal position on a suitable platform meeting the approval of the Engineer. Concrete shall be placed according to the applicable provisions of 703. The forms shall be overfilled, the surplus concrete screened off, and the top surface finished to a uniform, even texture similar to that produced by the forms. Each pile shall be marked with its casting date. If required, portions of the piling exposed to view shall be finished as provided in 703.19.

**(D) CURING.** Curing shall be performed as outlined in 703.18 except that the period of curing will be 14 days in lieu of 7 as specified. No piles shall be moved from their casting positions in less than 7 days nor be driven within 21 days after casting.

**(E) STORAGE AND HANDLING.** Removal of forms, curing, storing, transporting and handling precast concrete piles shall be done in such a manner as to avoid excessive bending stresses, cracking, spalling or other injurious results. Supports for handling cured piles shall not be more than 20 feet apart and computed stress in reinforcement shall not exceed 12,000 pounds per square inch, based on the calculated weight of the pile plus 100 percent of the same weight for impact and shock. During storage, piles shall be firmly supported at points not more than 4 feet apart throughout their length and shall be separated from each other at least 4 inches. When piles are stored in tiers, supports shall be placed directly over the supports for the lower piles. No tier shall contain more than 4 piles.

**(F) CAPS.** When the nature of the driving is such as to unduly injure the heads of the piles, they shall be protected by caps of approved design.

Care shall be taken to insure full bearing of the driving cap on the pile for proper and uniform distribution of the hammer blow.

**(G) SPLICES.** Extensions or splices shall be avoided wherever possible.

If required, the following procedures shall be met:

The concrete at the end of the pile shall be cut away, leaving the reinforcement exposed for a length of 30 diameters of the bars. The cut shall be perpendicular to the axis of the pile. Reinforcement similar to that used in the pile shall be lapped 30 diameters and fastened to the projecting steel. In placing the formwork for the extension, care shall be taken to avoid leakage along the pile. Prior to placing the concrete, the top of the pile shall be thoroughly wetted and covered with a thin coating of 1:2 cement mortar.

## **701.09 PRECAST PRESTRESSED CONCRETE PILES**

Precast prestressed concrete piles shall not be driven until the concrete has attained a compressive strength of not less than 5000 pounds per square inch, but in no case less than three days from the date of pouring.

Heads of the piles shall be protected in accordance with 701.08(F).

The prestressing strand shall have a minimum breaking strength for 7/16 inch strand of 31,000 pounds and a minimum load at one percent extension of 26,350 pounds with an initial load of 3100 pounds. The prestressing load applied to the strand shall be 21,700 pounds. Each reel of strand and all samples furnished to the Engineer for testing shall bear a tag identifying the strand as extra high strength.

Each end of the piles shall have extra reinforcement as shown on the plans. All prestressing strands shall be ground flush with each end of the pile.

The piles shall be constructed to a tolerance of -0 to +12 inch of the cross sectional dimensions shown on the plans. The tolerance from a straight line along the longitudinal axis shall be the same as specified for precast concrete piles.

Extensions or splices of pre-cast prestressed concrete piles shall be avoided whenever possible. However, if these splices are required the following procedure shall be employed.

After driving is completed, the concrete at the end of the pile shall be cut away, leaving the prestressing stand exposed for a minimum length of 24 inches for precast, prestressed concrete piles. Reinforcement as shown on the plans shall be lapped a minimum of 24 inches with the projecting prestressing strands. In placement of formwork for the exterior, care shall be taken to avoid leakage along the pile. Prior to placing the concrete, the top of the pile shall be thoroughly wetted and covered with a thin coating of 1:2 cement mortar.

## **701.10 TIMBER PILES**

Metal collars, bands, or other approved devices to protect the piles against splitting or brooming shall be provided where necessary.

Piles shall be pointed where soil conditions require it. When necessary, the piles shall be shod with metal shoes of a design satisfactory to the Engineer, the points of the piles being carefully shaped to secure an even and uniform bearing on the shoes.

Full-length piles shall always be used where practicable but, if splices cannot be avoided, an approved method of splicing shall be used. Piles shall not be spliced except by written permission of the Engineer.



The lengths of piles shall include ample allowance for fresh heading and for such depth as may be necessary to suit the Contractor's method of operation.

In the event that treated timber piles are specified, special care shall be taken to avoid breaking the surface. Cuts or breaks in the treated surface shall be given two brush coats of hot creosote oil meeting the requirements of 811.09(B).

The heads of piles shall be protected by caps of approved design.

## **701.11 MEASURE**

**(A) PILING.** The unit of measure for Timber, Precast Concrete, Cast-In-Place Concrete with Steel Casting, Steel H, Prestressed or Test Piles will be the linear foot.

The number of feet measured will be the actual number of linear feet left in the completed structure of piles acceptably driven, as measured along the axis of the pile from the tip of the pile to the cutoff elevation shown on the plans. No measurement will be made of cutoffs, broken piles or piles driven out of position.

### **(B) LOAD TESTS.**

**(1) STANDARD LOAD TESTS.** The unit of measure for Standard Load Tests will be each. The number will be the actual number of standard tests performed.

**(2) QUICK LOAD TESTS.** The unit of measure for Quick Load Tests will be each. The number will be the actual number of quick load tests performed.

## **701.12 PAYMENT**

**(A) PILING.** The number of linear feet of piling, as measured in 701.11(A), will be paid for at the contract unit price per linear foot for:

1. Untreated Timber Piles
2. Treated Timber Piles
3. Steel H Piles
4. Precast Concrete Piles
5. Cast-In-Place Concrete Piles
6. PreStressed Piles
7. Length Test Piles

of the type and size specified, which payment will include all labor, materials, tools, equipment and incidentals necessary to furnish and drive the piles completely in place.

Load test piles, whether or not they become permanent piles, will be paid at the contract price for regular piles of the type and size specified.

Payment for H Piles includes temporary and permanent pile splices and welding.

**(B) LOAD TESTS.** The number of Standard or Quick Load tests, as measured in 701.11(B), will be paid for at the contract unit price per each, which payment will include furnishing and removing all testing

materials, loading and unloading the piles, guide platforms and all other material, labor, equipment and incidentals necessary to complete the item as specified herein. Pile Load Test will not include cost of pile tested. Payment does include driving and removal of reaction and anchor piles, reaction and anchor piles left in place but not considered as permanent piles, backfilling holes left from pulled piles, jacking equipment and associated equipment necessary to complete each load test.